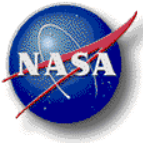


JET NOISE RESEARCH AT NASA

Brenda Henderson & Dennis Huff, NASA

A presentation outlining current jet noise work at NASA was given to the Naval Research Advisory Committee. Jet noise tasks in the Supersonics project of the Fundamental Aeronautics program were highlighted. The presentation gave an overview of developing jet noise reduction technologies and noise prediction capabilities. Advanced flow and noise diagnostic tools were also presented.



Jet Noise Research at NASA

Brenda Henderson & Dennis Huff
NASA

Naval Research Advisory Committee
January 7 – 8, 2009
Arlington, VA

Fundamental Aeronautics Program

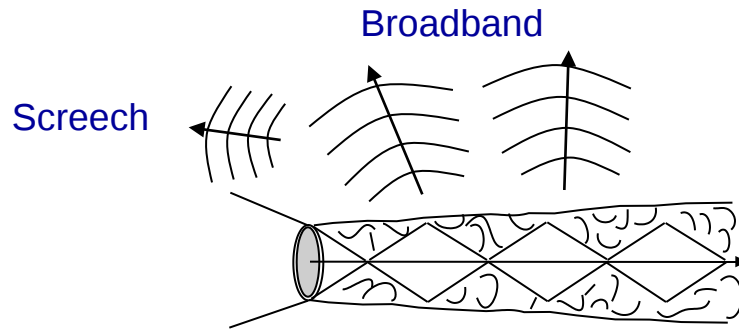


- Four projects
 - Supersonics
 - Subsonic Fixed Wing
 - Subsonic Rotary Wing
 - Hypersonics
- Supersonics Technical Challenges
 - Efficiency
 - Environment
 - Airport Noise
 - Prediction
 - Diagnostics
 - Engineering
 - Sonic Boom
 - High Altitude Emissions
 - Performance
 - Entry, Descent, and Landing
 - Multidisciplinary Design, Analysis, and Optimization

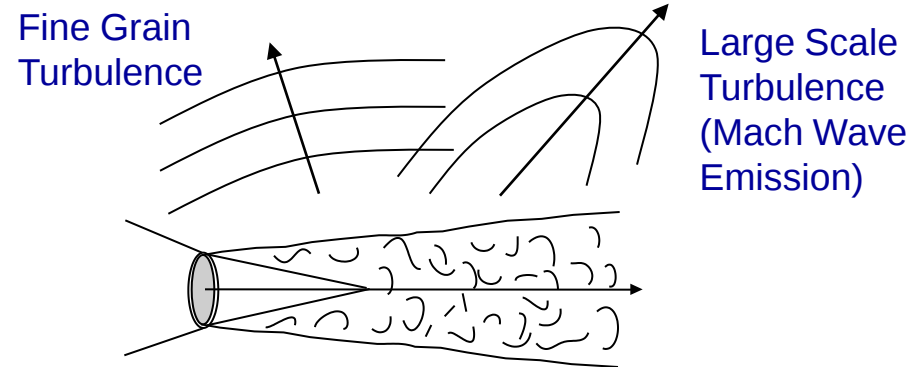
Critical Military Jet Noise Sources



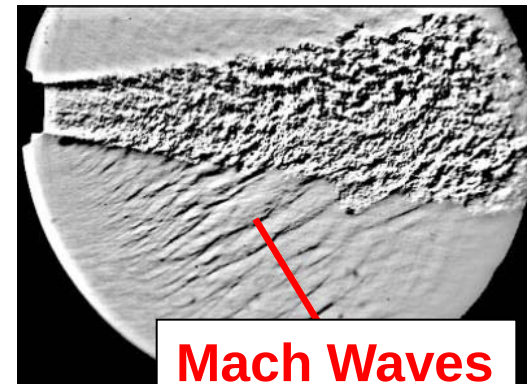
Shock Noise



Mixing Noise



- Mixing noise
- Mach wave radiation
 - Crackle
- Shock associated noise
 - Broadband
 - Discrete
- STOVL noise/tones



Courtesy of D. Papamoschou

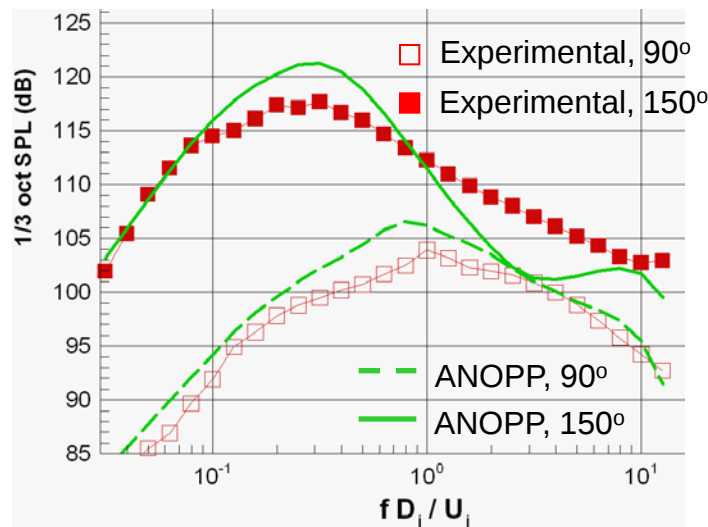
Modeling and noise reduction technology must address each of these differently depending on flight regime

Prediction

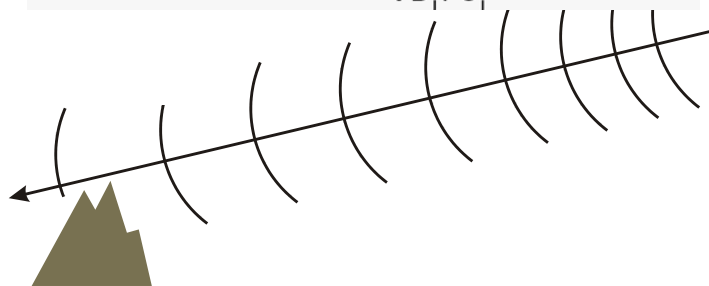
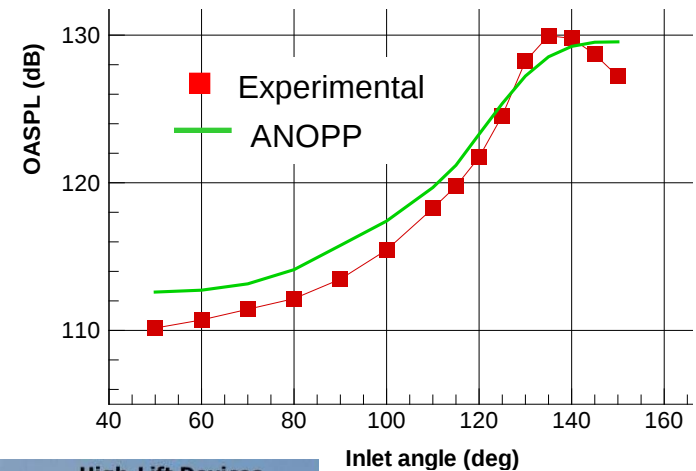
NASA Aircraft Noise Prediction Program: ANOPP

NASA POC: Casey Burley, Casey.L.Burley@nasa.gov

- **Total aircraft noise prediction capability for subsonic and supersonic aircraft.**
 - Predicts aircraft source noise, propagation and impact at receiver
 - Predominantly semi-empirically based methods
 - Ability to predict high speed jet mixing & broadband shock noise



$M_j = 1.2$
 $TT_R = 3.6$
 $BPR = 0.2$



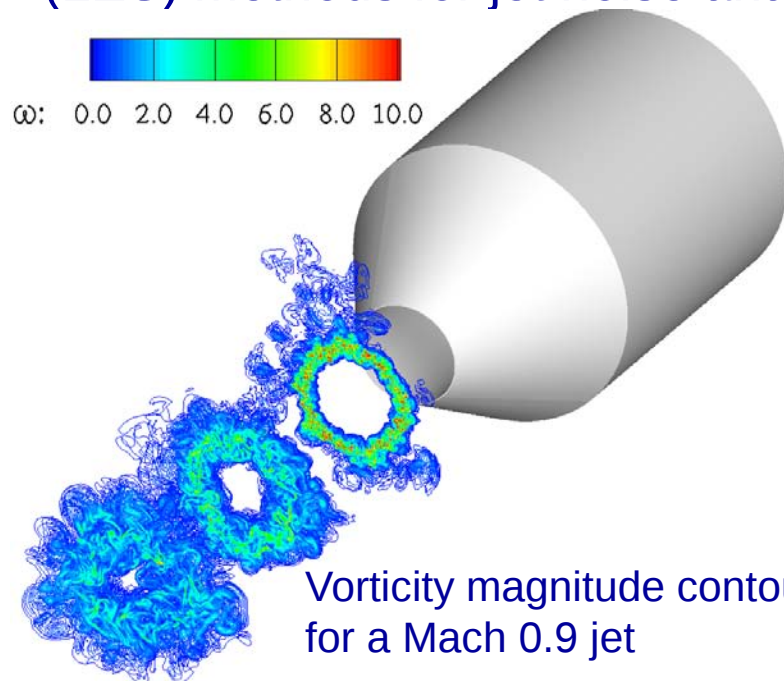
Receiver ← Propagation ← Source

Large-Eddy Simulation Research

NRA: Stanford University

PI: Sanjiva Lele

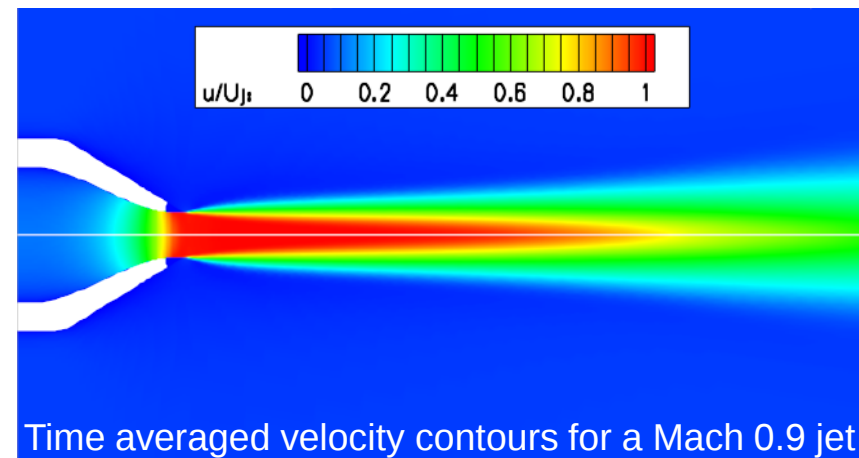
- Code development for time-dependent turbulent simulations of flowfields from noise suppressing nozzles
- Develop computational tools to couple Reynolds Averaged Navier-Stokes (RANS) and Large-Eddy Simulation (LES) methods for jet noise analyses.



NASA POC: Jim DeBonis

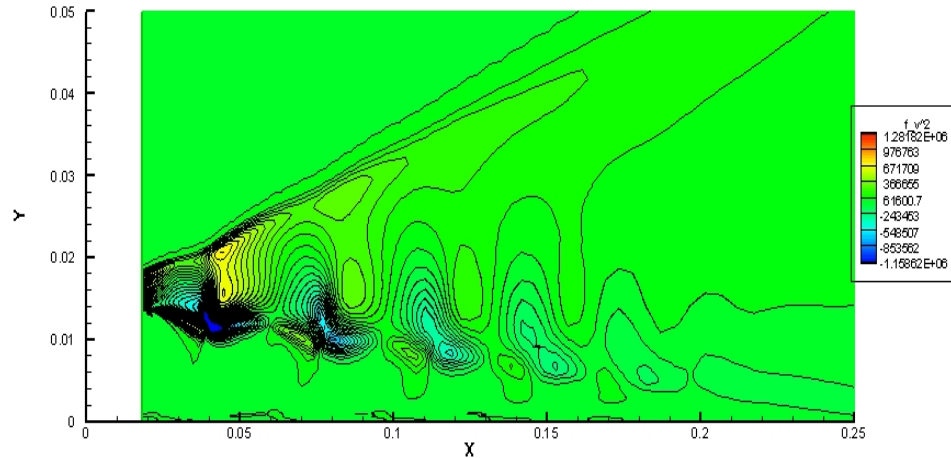
James.R.Debonis@nasa.gov

- In-house research code
- Low dispersion Runge-Kutta time stepping (1st - 4th order)
- High-order (2nd - 12th) central and DRP based spatial schemes
- Shock capturing filters

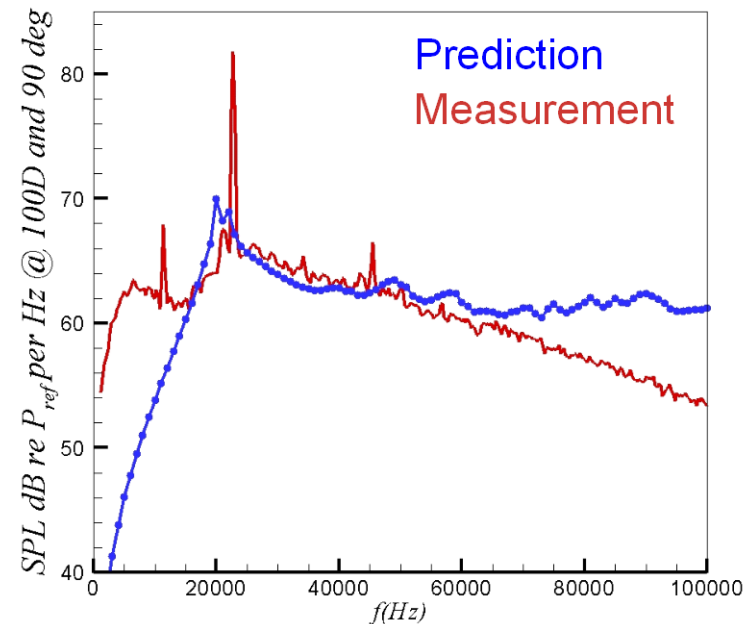


NRA: Pennsylvania State University, PI: Philip Morris

Source Strength Distribution



Far Field Radiated Noise Spectrum



- Noise model based on RANS CFD prediction for shock cell structure and on model for two-point turbulence statistics
 - Captures observed trends – reviewing details of turbulence source statistics to improve high frequency predictions
 - Requires ~1 hour per observer angle to compute

Improving Scale Model Noise Prediction

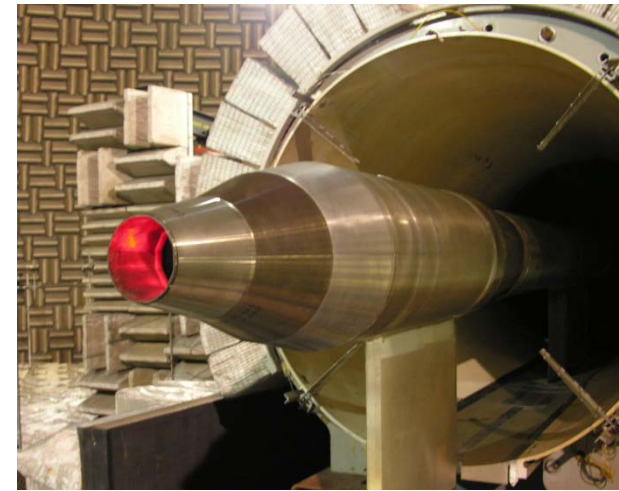
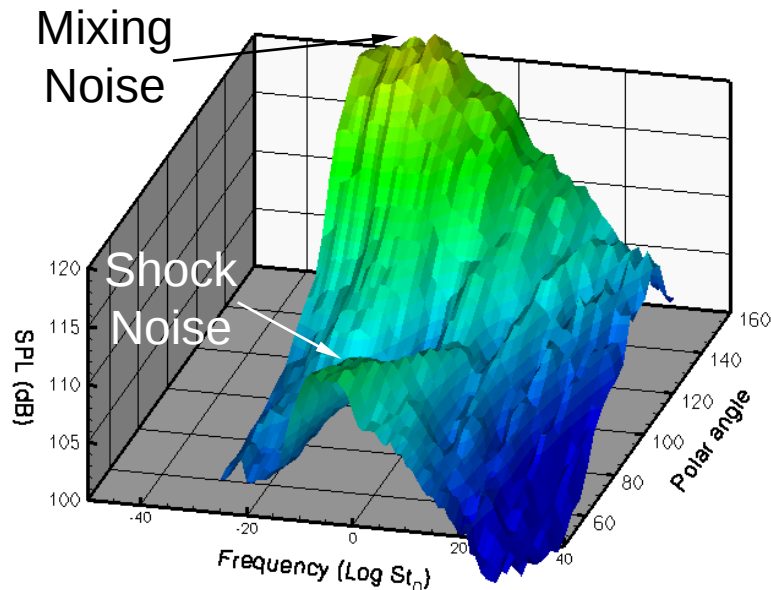


Funded by Strategic Environmental R & D Program (SERDP)

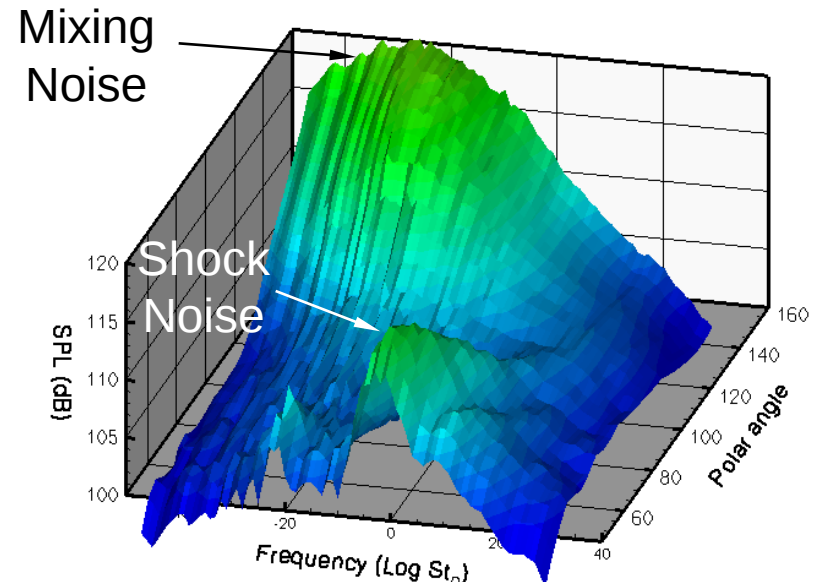
NASA POC: Tom Norum, Thomas.D.Norum@nasa.gov



F-15 ACTIVE Flight Test (1997)



Moderate Scale Tests



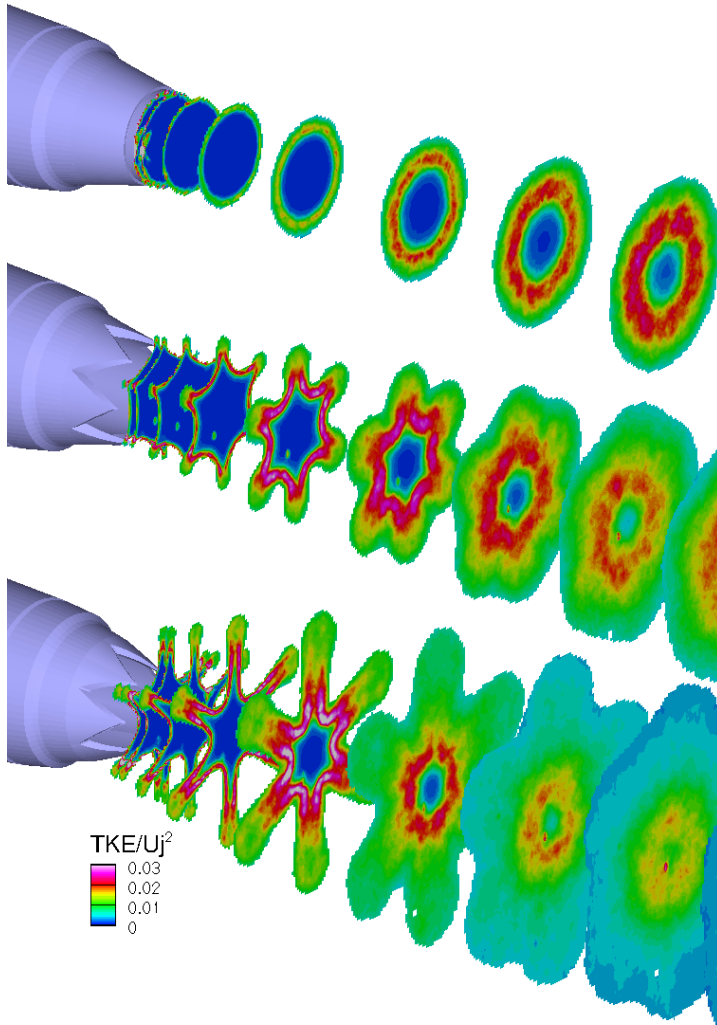
Diagnostics

Advances in Flow Diagnostics for Noise Reduction and Prediction

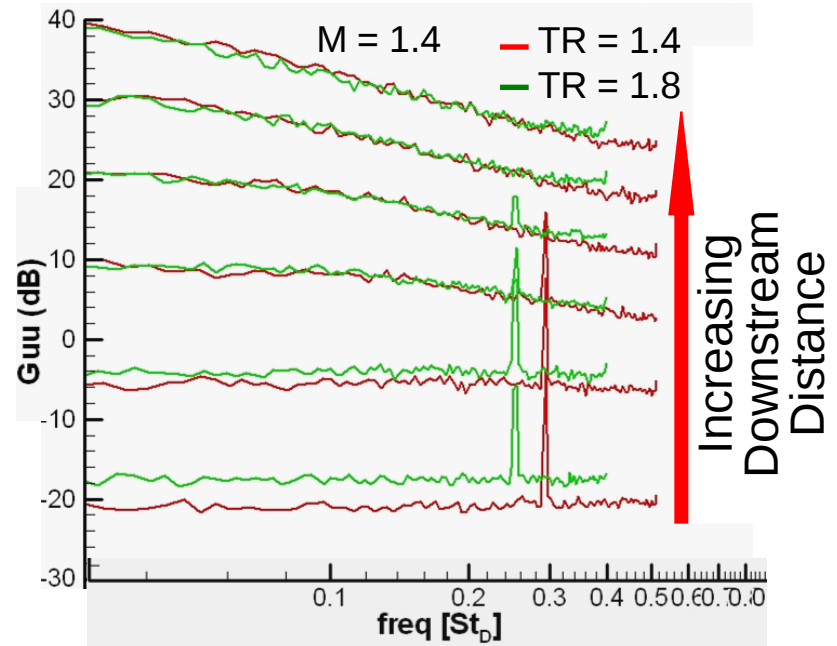
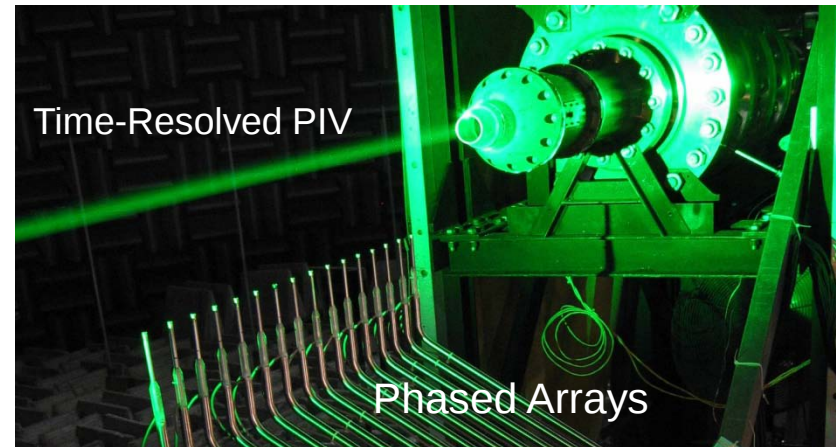


NASA POC: James Bridges, James.E.Bridges@nasa.gov

Turbulence measured in hot jets using Particle Image Velocimetry (PIV)



Flow-Source correlations explored using multiple advanced techniques



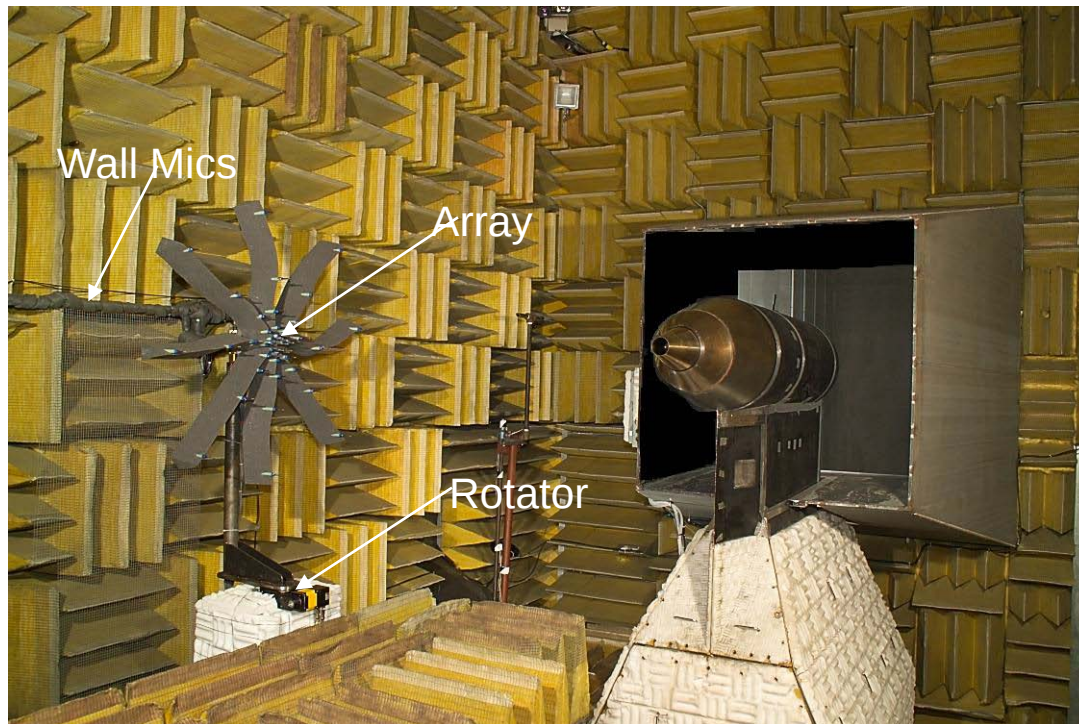
JEDA Measurements for Jet Noise



NASA POC: Tom Brooks, Thomas.F.Brooks@nasa.gov

Goals:

- Develop processing methodologies for incoherent and coherent convecting sources
- Characterize performance of array
- Obtain detailed source distribution maps for subsonic and supersonic exhausts
- Obtain data for validation of prediction codes

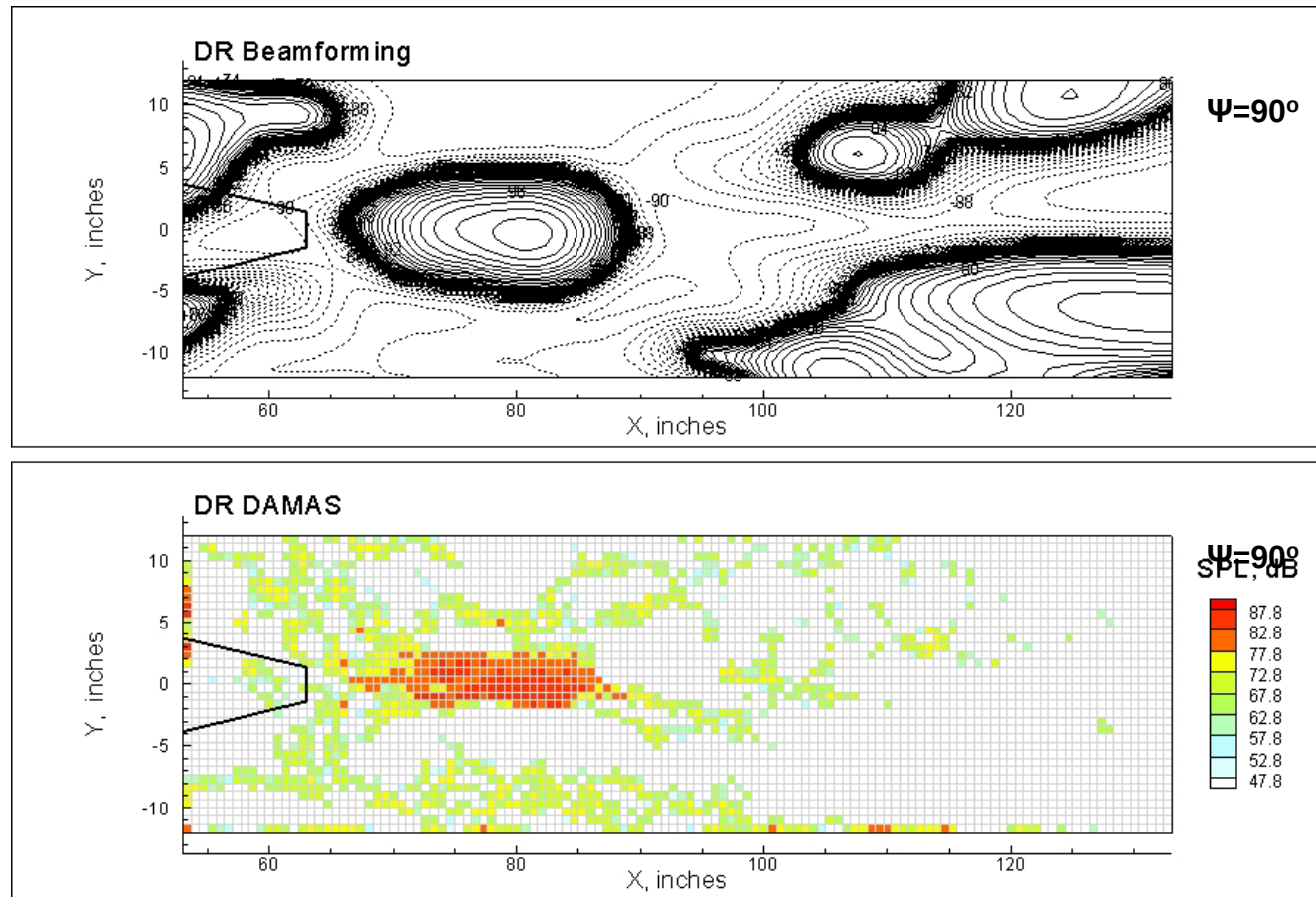


Array Installation

Supersonic Measurements with JEDA



Convergent / Divergent Nozzle, NPR = 2.27, $M_j = 1.15$, $f_{1/3} = 12.5$ kHz

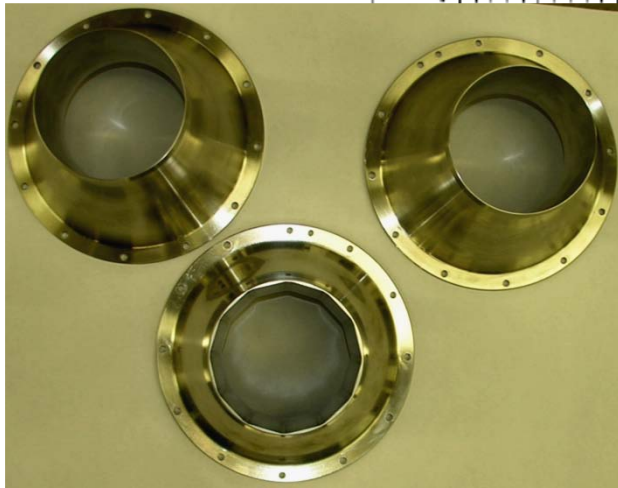
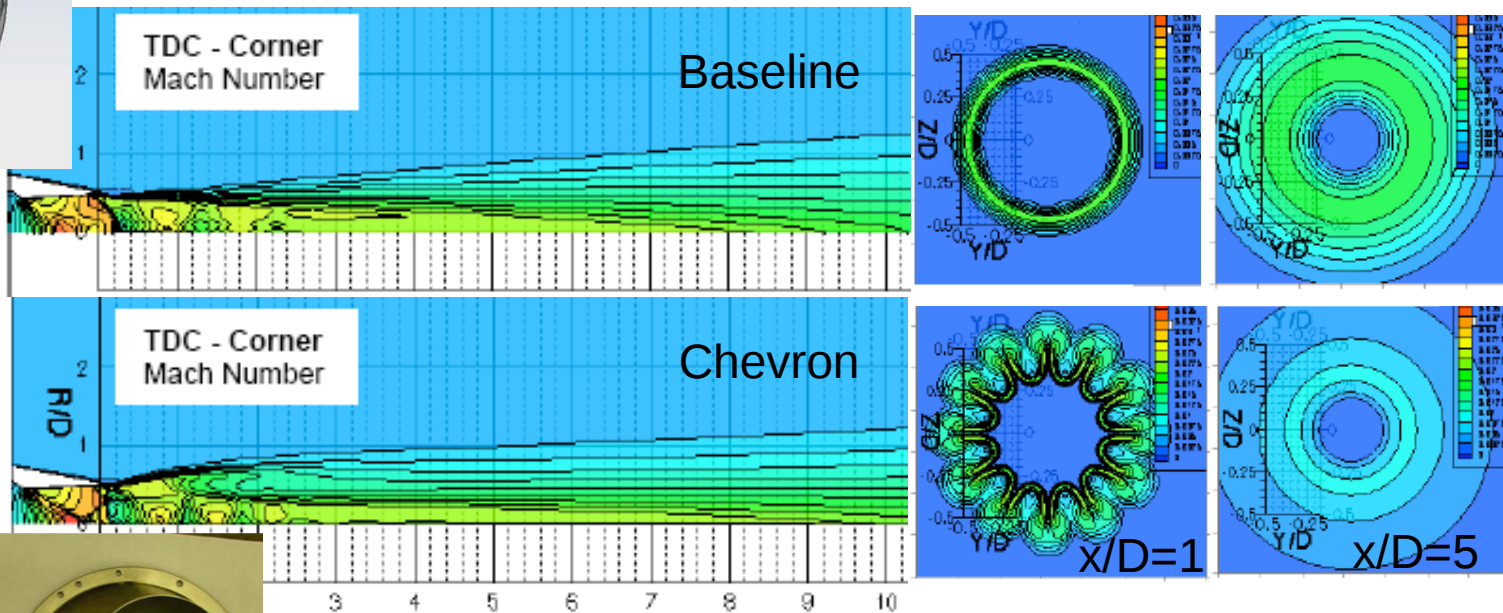


(Non-coherence assumption DAMAS processing – preliminary results)

Engineering

Mechanical Chevrons for Noise Reduction

Funded by Strategic Environmental R & D Program (SERDP)
NASA POC: Tom Norum, Thomas.D.Norum@nasa.gov



Investigate impact of nozzle geometry and chevron parameters on radiated sound

Supersonic Jet Noise Suppression Using Plasma Actuators



NRA: The Ohio State University

PI: Mo Samimy

- Various jet instabilities are manipulated to mitigate noise
- Large Eddy Simulations used to predict optimal jet forcing for noise mitigation

Example of actuation effects on the jet flow field

Image of
baseline Mach
1.3 jet

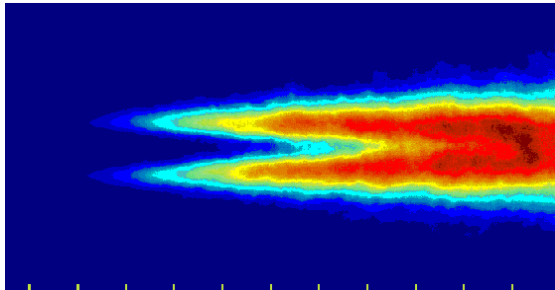
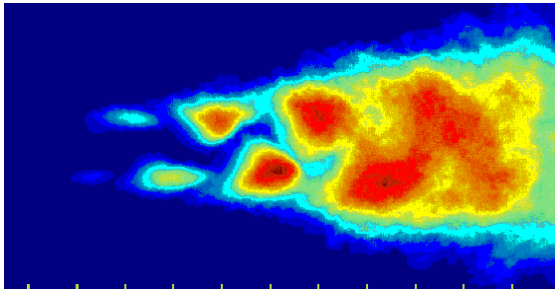
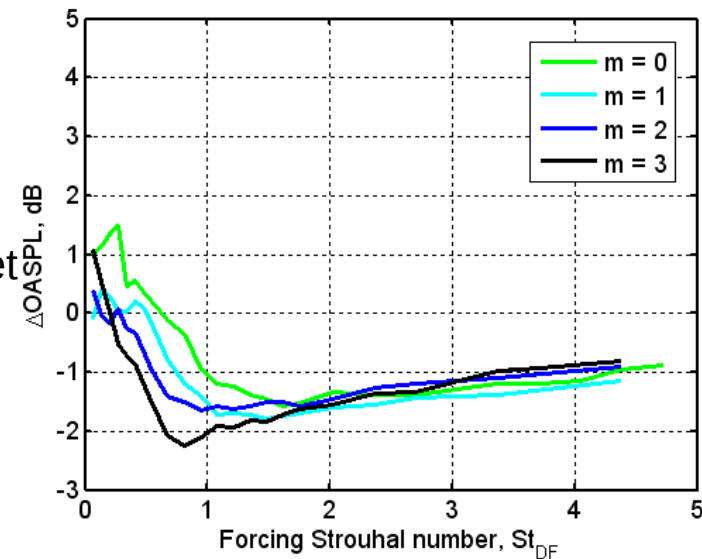


Image of forced
jet at 5 kHz and
at azimuthal
mode $m=1$



Example of noise mitigation at Mach 1.3

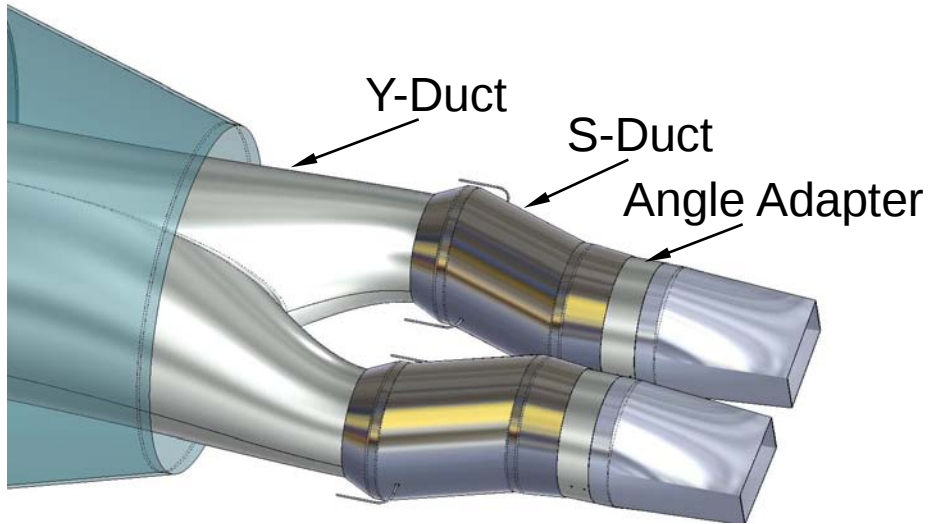
Noise
reduction
relative to
baseline jet
(actuation
not
optimized)



Twin Model for Jet Interaction Studies



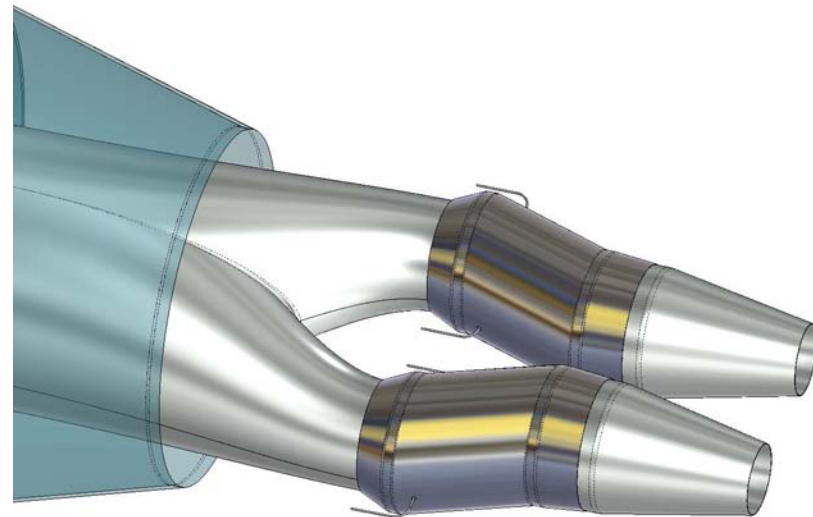
NASA POC: Brenda Henderson, Brenda.S.Henderson@nasa.gov



Investigate

- Jet plume interactions
- Noise characteristics of rectangular nozzles

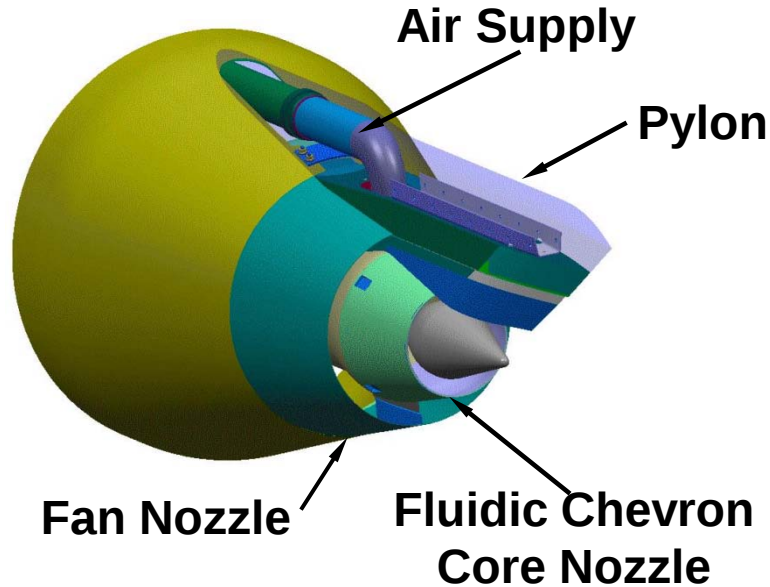
- Critical design review - Dec. 11
- Model delivery - March, 2009



Fluidic Chevrons for Noise Reduction



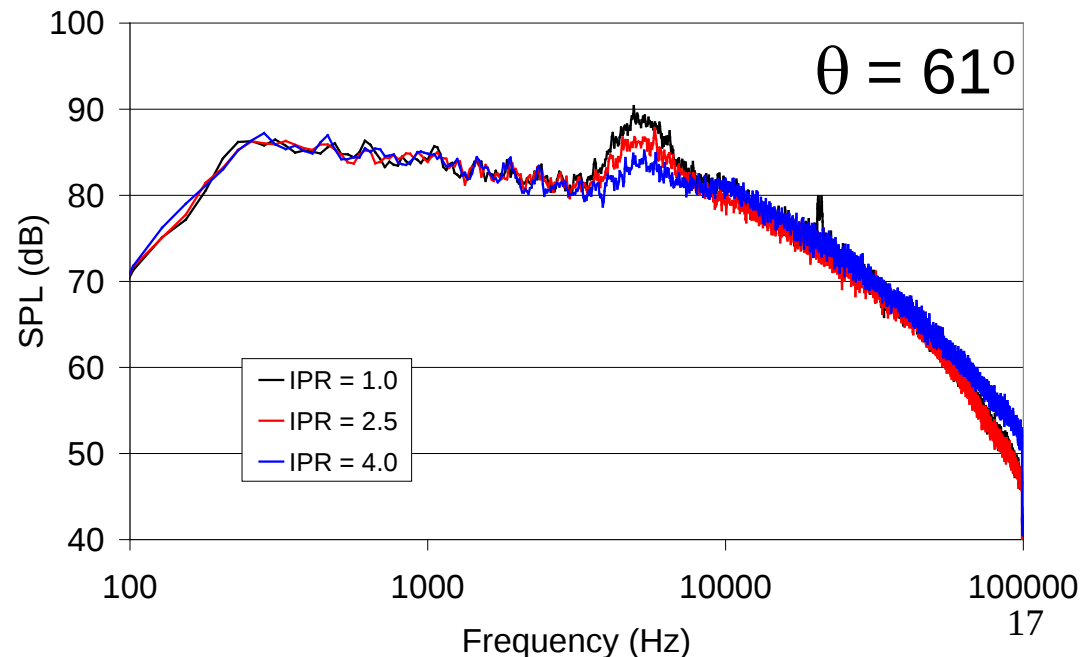
NASA POC: Brenda Henderson, Brenda.S.Henderson@nasa.gov



$$\text{NPR}_c = 1.61$$

$$\text{NPR}_f = 2.23$$

- Air injection nozzles tested at subsonic and supersonic exhaust speeds
- Mixing noise and broadband shock noise reductions achieved for some configurations and operating conditions
- Nozzle design resulted from partnership between NASA and Goodrich Aerostructures





- Prediction
 - ANOPP
 - LES
 - Statistical models for broadband shock noise
 - Scale model and flight data databases
- Diagnostics
 - PIV
 - Time accurate PIV
 - Phased array
- Engineering
 - Chevrons
 - Plasma actuators
 - Twin jet studies
 - Fluidic injection



Solutions need to be practical and combine source reduction, transmission path modifications and receiver protection.

Source

- Chevron nozzles, variable area nozzle optimization, novel mixing methods
- Cutback after takeoff

Transmission Path

- Barriers for near-field noise isolation and reduction
- Noise abatement flight paths

Receiver

- Hearing protection
- Acoustic enclosures

Run-Up Jet Noise Suppressor – Historical Perspective

23 dB Noise Reduction At Peak Angle

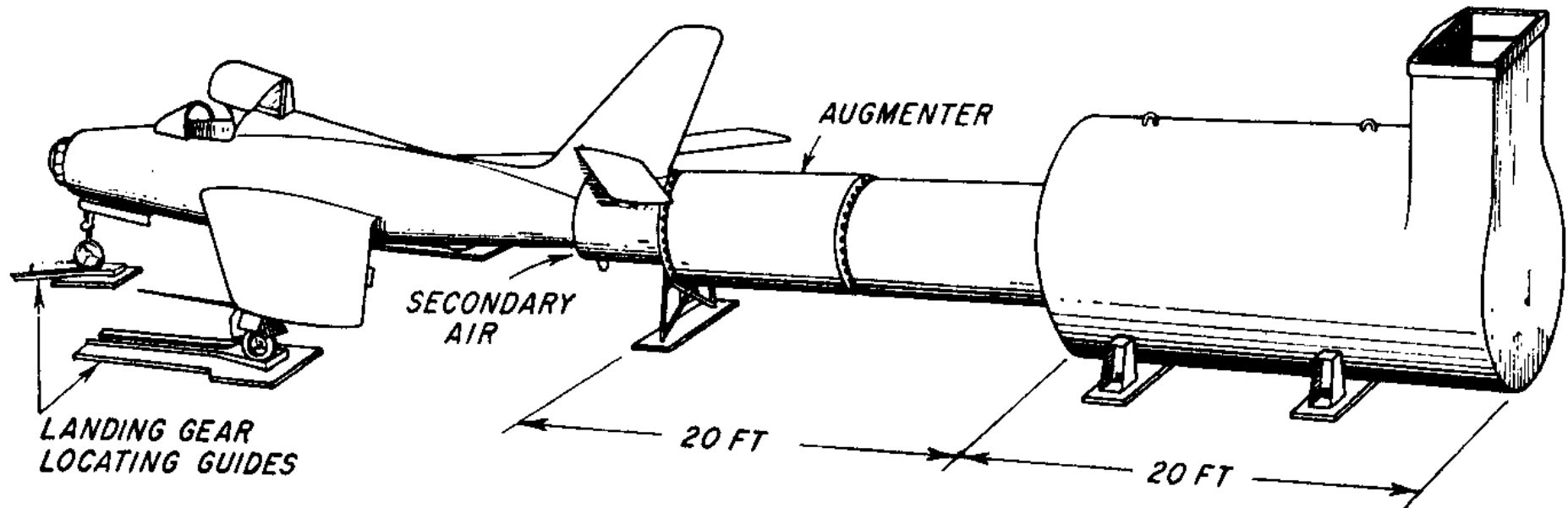
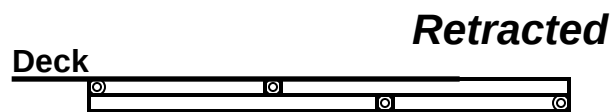
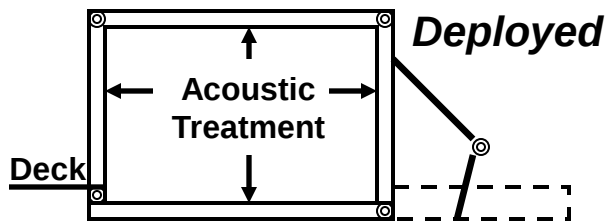


FIG. 34.19. Run-up noise suppressor for jet aircraft (F-84 powered by J-65, 7,200-lb thrust) utilizing mainly nondissipative elements for noise suppression (sound-absorbing resonant chambers). This muffler is reported to reduce the over-all jet noise under the angle of maximum radiation for the unmuffled aircraft by 23 db. No water cooling is used with this particular design. (Courtesy Industrial Acoustics Co.)

Reference: Harris, C.M., Handbook of Noise Control, McGraw-Hill, Inc., 1957

Notional Jet Noise Barrier



- Actuated acoustic barrier.
- Interior lined with acoustic treatment (possibly metal foam).
- Addresses run-up jet noise to shorten exposure duration.
- If feasible, add “chutes” to breakup jet plume to increase peak frequencies and increase treatment effectiveness.
- Noise measurements can be made using a prototype barrier and ground run-ups to quantify benefits (will not get 23 dB).
- This design is not best for acoustics, but should be practical.

Pros: No aircraft mods or performance impact, relatively low cost.

Cons: Requires mods to carriers, only addresses takeoff noise.



Takeoff With Engine Cutback

- **Commercial aircraft throttle engines back after takeoff to reduce jet noise until a sufficient altitude is reached to resume a higher climb rate.**
- **For noise sensitive communities, a similar cutback procedure should be considered for tactical aircraft.**
- **To see if this is feasible, we can use the SEL flyover data (Porter briefing):**
 - 1) Determine acceptable noise levels for legacy aircraft.**
 - 2) Apply corrections for the number of daily operations for new fleet mix.**
 - 3) Compare this noise level with Min/Max range for F-35 and determine power setting.**
 - 4) If F-35 still has a positive climb rate, we have a solution.**

Other Thoughts



- This problem is extremely difficult. Commercial aircraft noise reduction with steady support over many years and has yielded approximately 0.3 dB noise reduction per year since the 1960's (average EPNdB for three certification points). We are looking for 17 dB without the benefit of changing the cycle of the engine to reduce the exhaust velocity, which has been the primary method for reducing commercial aircraft jet noise.
- Since changing the engine cycle is not practical in near term, source reduction methods will have limited benefits. They are worth pursuing since they will reduce both near field and community noise.
- Transmission path modifications and receiver protection is probably the only way to come close to noise goals.
- Should explore which functions on deck could be done remotely or at a different location in combination with sensors/cameras. Can we move toward using robotics? Can people move into acoustic enclosures during takeoff and landing?